under the influence of physico-chemical processes of the same order as those that must have been operative in the past.

* * * * *

In my work entitled "The Nature and Origin of Living Matter," an abridgment of which has been published by the Rationalist Press Association,[5] I have considered the question of "spontaneous generation" from a broader point of view (pp. 128–141), and have endeavoured to show how multitudes of facts can be explained in accordance with my views, that from the time when living matter first appeared upon the earth it has probably ever been constantly re-appearing, as at present, and giving birth to the simplest living units, such as now swarm upon its surface. These processes are such that they must always take place beyond our ken, seeing that they necessarily begin with mere molecular collocations, gradually going on to the formation of particles of an ultra-microscopic order. Such infinitesimal particles gradually emerge into the region of visible things as revealed by high powers of the microscope, and take on this or that simple organic form in a manner that (though by processes much more complicated) is somewhat akin to the mode by which crystals emerge from different mother liquors, and take on this or that particular crystalline form.

Thus, while the fact of the present occurrence of the *de novo* origin of living matter is, in my opinion, beyond the region of doubt, I fully recognise that the actual steps of the process remain to be discovered. I have elsewhere[6] referred to some of the probable steps of the process, and the prominent part that may be taken by inorganic catalysers under the influence of sunlight, and in some quite recent experiments by Prof. Benjamin Moore and J. A. Webster, in a paper entitled "Synthesis by Sunlight in Relationship to the Origin of Life,"[7] they have been able to demonstrate the probable actual first step of such a process —one that is known to occur as a first step in the nutrition of plants. We are, however, as yet only on the threshold of anything like an explanation of the various stages of this supreme mystery, for the unravelling of which philosophers and chemists have hitherto striven in vain. As with many other natural phenomena, the fact of the occurrence of which cannot be questioned, so here only conjectures are available as to the precise mode in which it may have been brought about. We must, however, repose our faith in the uniformity of natural phenomena, as one of the cardinal postulates of science, and if living matter had a natural origin in the far-distant past, there is, from that point of view, good ground for believing what our experiments seem to testify, that it also occurs at the present day.

H. CHARLTON BASTIAN.

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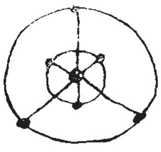
[5] Watts and Co., 1910.

[6] "The Origin of Life," 2nd edition, 1913, pp. 61–65.

[7] Proceedings of the Royal Society, B. 593, p. 163.

Atomic Models and X-Ray Spectra.

It is universally assumed that the atom of an element can form a Saturnian system with more than one ring of rotating electrons, and this idea is used in particular by Moseley in the theoretical discussion of his recent experiments. But in an Adams prize essay, not yet published *in extenso,* this is shown to be impossible. If the law of repulsion between two electrons, or of attraction between electron and nucleus, is that of the inverse square, more than one *coplanar* ring cannot exist. All the electrons in any plane must lie in the same ring, and even if they are in different planes, the radii of the rings must be nearly equal. A consideration of a simple case will illustrate this. For example, it is at first sight probable that the system in the accompanying diagram, consisting of two coplanar rings of three electrons each, symmetrically arranged with all the angles equal to 60°, can exist with some angular velocity ω, if the radii of the outer and inner rings are a and b, the latter being much smaller than a. But it is easily shown that the conditions of steady rotation of such a system are—



$$\frac{m\omega^2}{e^2}=\left(\mathrm{N}-\frac{1}{\sqrt{3}}\right)\frac{1}{a^3}-\frac{1}{a(a+b)^2}+\frac{b-2a}{a}\cdot\frac{1}{(a^2+b^2-ab)^{\frac{3}{2}}}$$

$$=\left(\mathrm{N}-\frac{1}{\sqrt{3}}\right)\frac{1}{b^3}-\frac{1}{b(a+b)^2}\quad\frac{2b-a}{b}\cdot\frac{1}{(a^2+b^2-ab)^{\frac{3}{2}}}$$

and the resulting equation for the ratio b/a has only *one* root $b/a=1$, whatever value be attached to N, where Ne is the charge on the nucleus. Any other simple case which is tried will be found to lead to the same conclusion.

This conclusion not only belongs to any ordinary dynamical theory of the rings, but to Bohr's theory also. For Bohr supposes that the *steady rotation* of the system can be derived by ordinary mechanics, and, in fact, the equation so derived is vital to his formula for spectra. If Bohr's theory is to remain—and it is so attractive that its retention is desirable, in the writer's opinion—we must give up the idea of concentric rings in the atom, with X-radiation coming from an inner ring. For any way of avoiding the present conclusion, for example, by making a change in the law of attraction in the immediate neighbourhood of the nucleus, at once destroys the formula on which Moseley bases his view that his experiments support Bohr's theory.

How then, if there is only one ring of electrons, and if X-radiation is due to a ring—a point on which Moseley has given a cogent reason for doubt—does X-radiation originate? The answer is that without a serious reduction in its radius, the single ring may, on Bohr's theory, give radiation of the X-ray type. For Bohr's spectral formula for an atom with nucleus Ne and n electrons is

$$\nu=\frac{2\pi^2me^4}{h^3}(\mathrm{N}-\mathrm{S}_n)^2\left(\frac{1}{\alpha^2}-\frac{1}{\beta^2}\right)$$

where α in the Balmer series is 2, and β takes integral values. But the principal line given by the formula corresponds to $\alpha=1$, $\beta=2$, and its wave-length in cm. is at once found to be

$$\lambda=\frac{1215{\cdot}7\quad 10^{-8}}{(\mathrm{N}-\mathrm{S}_n)^2}$$

To obtain a wave-length $\lambda=3{\cdot}368.10^{-8}$, Moseley's value for calcium, we only require $\mathrm{N}-\mathrm{S}_n=18{\cdot}98$, which Moseley interprets as meaning $\mathrm{N}=20$, $n=4$. Thus a ring which gives the ordinary hydrogen spectrum when $\mathrm{N}=1$ can give an X-ray spectrum when $\mathrm{N}=20$, in spite of the enormous difference of wave-length concerned. But the *radius* would not be so widely different in the two cases. For in the normal atom it is inversely as $\mathrm{N}-\mathrm{S}_n$, and since on Bohr's view, the radius of a hydrogen atom is $5{\cdot}5.10^{-9}$ cm., that of calcium would be $3{\cdot}10^{-10}$, quite a possible value.

There is ground, accordingly, for retaining Bohr's theory, if only one ring exists, and then the calcium X-ray spectrum means exactly the same thing as the ordinary hydrogen spectrum, and no element should show such X-ray spectra until N becomes large. The X-ray or Balmer spectrum of helium, for example,

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would have a principal line, $\lambda = 694 \cdot 5 . 10^{-8}{}_0$, between the ultra-violet and the X-ray regions.

But there is a serious difficulty. If $N = 20$, $n = 4$, where are the other 16 electrons required to make the atom neutral? Perhaps it is more reasonable to suppose that N for calcium is higher, and given by $N - S_N = 19$. In this case, N would not denote the place of the element in the periodic table, but would allow for intermediate and unstable forms of matter—an allowance which may well be necessary. The only alternative is to explain X-rays by the structure of the nucleus. Any internal ring must be one of doublets, such as neutral α particles.

There is one other point to which I must refer. Mr. Moseley states that he has not found a correspondence between the X-ray spectra and the vibrations of the element nebulium treated in one of my papers. This correspondence is not to be expected, for the two investigations are unrelated. The simple-ring atoms which I have used to interpret astrophysical spectra are supposed to have a *simple* nucleus, or to contain no α particles, and to be incapable of giving series spectra. They are not identical with ordinary atoms, into which, however, they appear to change in the stars which follow nebulæ in order of evolution, and, as is shown in a paper in the *Monthly Notices of the R.A.S.* for December last, almost certainly by a modification of their nuclei. When this change occurs, they show series spectra, which must depend on the nucleus, and perhaps on tubes of force, in a way which a mechanistic interpretation of Bohr's theory may perhaps explain. In a paper read at the January meeting of the Royal Astronomical Society, these series were shown to lead to the same conclusion as Bohr's with regard to the nature of a hydrogen atom.

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Prof. Turner and Aristotle.

IN *The Times* report of December 29, 1913, of Prof. Turner's lecture at the Royal Institution, his remarks on Aristotle are summarised in a way which will surely appeal to his sense of humour after his astonishment at my letter has abated.

"Aristotle said that a weight of 10 lb., for example, fell ten times as fast as a weight of 1 lb., and the world went on believing it for 2000 years. This raised the question whether it was better to believe things just because people told one, or to try to find out for oneself."

Aristotle never said this at all. Who first fathered it on to him will perhaps never be known now, but since Galileo made the statement notorious 323 years ago, the world has gone on believing it. If anyone wishes to find out for himself, let him consult the Teubner stereotyped Greek edition of Aristotle's "Physics," Book IV., cap. viii., sect. 8–11, or the Leonine edition of St. Thomas Aquinas's "Opera Omnia," tome ii., commentary on Aristotle's physics, texts 71 and 74, pp. 183–7. It is in the British Museum.

Aristotle is discussing the notion of a vacuum, and using the argument from motion. Lection xi. in "Opera Omnia," containing the argument, begins on p. 180, and is headed, "Ex parte motus ostenditur non esse vacuum separatum." An intelligible paraphrase of the important parts of texts 71 and 74, or sect. 8 and 11, is as follows:—"§ 8: We see that a heavy body is borne (or translated) faster for two reasons, either because of differences in the medium through which it passes, as earth or air or water, or other things being equal, because the body itself differs by reason of its superior gravity or buoyancy. As regards the medium, the reason is that it resists. . . . If air is twice as subtile as water, then for an equal distance the time of translation in water will be twice that in air. . . . § 11: As regards differences in the body itself. We see that those bodies which have greater potentialities of movement (ῥοπὴν, inclinationem), whether downwards by reason of their weight, or upwards by their buoyancy, other things being equal as regards their shape (σχήμασι, figuris) are translated quicker over equal spaces, and this according to their proportionate magnitudes. But why should this be so in a vacuum? Therefore a vacuum is impossible. But why is it that they have different rates of translation? In a plenum it is indeed of necessity, for that body which is the faster, is so by reason of its power or of its shape or of its potentiality of motion whether of translation or projection, whereby it divides the medium more effectively. But in a vacuum all are equally effective, so that all are faster than one another. Which is impossible." § 11 is usually relied upon to convict Aristotle of error, but it is evident that motion through a resisting medium is premised.

The commentary of the Angelic Doctor makes this quite clear. The reader will find, probably to his amazement, that the new and modern notions of velocity were explicitly present to his intellect when he wrote. Special attention may be directed to § 13 of the commentary on p. 187, beginning "Deinde eum dixit, Secundum autem eorum." He actually used the words, "vel propter aptitudinem figurae quia acutum est penetrabilius," just as though he was describing the peculiar property of a modern pointed bullet. In the new and technical language of gunnery "motus" or "motus naturalis" is rendered precisely by the expression, "terminal velocity," the velocity at which the retardation of the medium, air, is exactly equal to the acceleration of gravity, resulting in a constant speed of fall. That Aristotle ever supposed for an instant that a 2-lb. weight fell, in the ordinary sense of words, twice as fast as a 1-lb. weight is an absurdity. What he taught was that the terminal velocity of a heavy body, such as Prof. Turner's sovereign, was greater than the terminal velocity of a light body, such as a feather, in a medium such as air or water. A penny can never fall faster than about 30 ft. a second through air. I performed the experiment last week, dropping pennies from Clifton Bridge, 250 ft., into the Avon. They take eight or nine seconds to reach the water. Sir George Greenhill has often expressed doubts to me as to the correctness of the accusation against Aristotle's common sense, but could never persuade a scholar to find the passage. A year and a half ago he showed me the above reference in the introduction of Mr. Lones's new book on Aristotle's "Natural History," and asked me to look it up. I consulted St. Thomas's Commentary in the British Museum, with the startling result I have mentioned, and fetched my former professor over to the reading-room to verify my discovery. That he did verify it must be my apology as a soldier for intruding into the domains usually preserved for scholars and philosophers of the highest order.

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27 Cranbrook Road, Bristol, January 9.

TEUBNER'S edition of Aristotle's "Physica" is out of print, but the equivalent passage is found in his Aristotle's "De Coelo" (C. Prantl), p. 73, where the law is enunciated that the terminal velocity of a body in a medium is proportional to the weight.

Aristotle's law was justified by Newton in his ex-

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